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growing scholars around them, the next being a consciousness that they are responsible for what they do to the world of science and letters, and not merely to their own colleagues and followers; and, finally, they must not only be fairly paid, but must be protected from temptations to every form of extravagance in the employment of their resources. Such are some of the difficulties which are to be encountered when the simple idea of 'first-rate teaching' is expanded.

All that Mr. Bryce says about the end of an education is excellent: "It is not to train students merely as lawyers, physicians, clergymen, engineers, bankers, merchants, and statesmen, but as men; and the best thing the university can do for them is to form in them what we will call the philosophic mind."

THUNDER-STORMS.

BENJAMIN FRANKLIN once remarked, in substance, sadly to a friend, "It is now eight years since I showed that mankind could be protected from the danger of lightning by lightning-rods; yet there is hardly a house in Philadelphia provided with them." The heart of the great American philosopher would be greatly warmed if he could perceive the activity of his disciples, who waylay every builder of a house, and awaken fears where all was peace before. There is no question oftener asked of the professor of physics than this: "Shall I put lightning-rods on my house, and, if I erect them, what should be their form and position?" Personally I have given the following abbreviated answers. "If your house is surrounded by tall trees, or if there are higher houses in your immediate neighborhood, I should trust to the trees, or kindly leave the expense of the lightning-rods to your neighbor. If your house stands alone, a prominent point in the landscape, on a cliff, or remote from trees, I should be in favor of a properly placed lightning-rod. I should place two or three pointed rods three or four feet above the highest point of the house; allow the metallic rod, which should be at least one-half a square inch in section, to rest, without glass insulators, upon the house; connect all the tin sheathing, the copper gutters, the gas and water pipes, with this lightning-rod; and conduct the latter, by the shortest course possible, to *wet earth*."

These answers seldom conclude the correspondence, however, although one generally prefers to leave to the neighbor the expense of erecting lightning-rods. One brings instances of houses having been struck which are situated lower than one's neighbors, and are surrounded with tall trees which over-topped the houses; and one asks with a shudder, "Can I connect my gas-pipes with a lightning-rod?" Indeed, the writer or would-be authority on lightning-rods has not an easy life before him. He must not only satisfy the timid heart of the believer in him, but he must also fight with all his knowledge the brazen limb of ignorance and superstition, who starts with the postulate that no scientific man knows any thing concerning thunder and lightning, and that the true knowledge has been revealed only to himself while working in a cornfield. It is not long since, that an American professor of physics was sued for twenty or thirty thousand dollars damages for maintaining that the members of a lightning-rod company which placed lightning-rods like a letter U upon the roofs of houses were practically quacks; the theory of this lightning-rod being, that the lightning, if it struck one point of the U, would be dissipated into the air from the other point. There is a lightning-rod company in Massachusetts at the present time which erects lightning-rods on the theory that lightning always seeks electrical earth-currents; and, if there are earth-currents beneath a house, that house should be protected, and the rods led into the path of the earth-current. If, on the other hand, no earth-currents run near the house, such a house is safe, and needs no lightning-rods. The electrician of this firm is self-taught: there are no books on electricity in his library. He discovers the earth-currents by a forked stick. Not deterred by the fact that there is no evidence to prove that a discharge takes place between a charged cloud and a current of electricity in the ground, and, moreover, no evidence to prove that earth-currents move in regular paths through the earth, and, indeed, no *conclusive* evidence of the existence of earth-currents, he persuades even the so-called practical electrician to rearrange the lightning-rods on his house.

The student of electricity is therefore called upon to assert the grounds of his belief: and he finds it difficult to convince his audience; for they are, in general, not sufficiently conversant with electrical phenomena to appreciate his arguments. The position taken by most professors of physics on the subject of lightning-rods is based upon the experiments of Franklin, in which he showed that pointed metallic rods,

so to speak, facilitated electrical discharges; the experiment of Faraday, by which it was shown that a person, and even the most delicate electrical instruments, inside a large metallic cage which was connected with the ground, were unaffected by powerful discharges of electricity between the cage and the prime conductor of an electrical machine; and the statistics collected by the English government, which show, that, since vessels have been provided with lightning-rods, the number of casualties produced at sea from lightning have been greatly reduced. A building covered by a metallic netting suitably connected with the ground would be well protected from lightning. The nearest approach to this condition of safety would be to connect all the network of metallic conductors about a house with wet ground; and one argument against placing under ground the network of telephone and telegraph wires in cities is, that at present, where they are very numerous, they protect buildings from danger from lightning. This is, of course, not the case where a single telephone or telegraph wire enters a house. The latter should always be well connected with the gas or water pipe. In regard, however, to the belief that tall trees, higher than the houses in their immediate neighborhood, protect the houses, we can point to the well-known efficiency of small points in facilitating electrical discharges by slow degrees. Each leaf and twig is such a small point. Moreover, during a rain, the dripping from the leaves reduces the electrical charge on the tree to the same sign and amount as that of the air in the immediate neighborhood, as is shown by the well-known experiment of Sir William Thomson, in which an insulated can, from which a stream of water issues in drops, is connected with an electrometer; and the latter shows that the metallic can has taken the charge of the air in its neighborhood. The drops of water continually reduce the can to the electrical potential of the neighboring air. The tree, therefore, can be looked upon as a more important electrical factor than the few salient lower points of a building.

It is safe to affirm that not one out of a thousand lightning-rods at present upon our buildings are of any use, for the simple reason that they are not led into moist ground, and therefore offer great resistance to the passage of an electrical discharge. Any one can be convinced of this by scraping the lightning-rod at any point, connecting a bright wire at this point, and, having led the other end of the wire to the water-pipe or to a body of water, placing

one or two Leclanché cells in this circuit, and leading the wire in a north and south direction directly over an ordinary pocket-compass. If the lightning-rod enters moist ground, or makes a connection with the earth, the compass should indicate an electrical current by its deflection. Generally it will be found that no such earth-connection exists, and the lightning-rod is therefore worse than useless. It should be immediately connected with the water-pipe, or with a spring, or some body of water. To illustrate the fact that the mere entrance of a metallic rod into the ground is not enough to insure the passage of an electrical discharge to the ground, drive two metallic rods into your lawn, at any suitable distance apart; connect them by a wire, which includes a Leclanché or other voltaic cell; and, having led the wire over a pocket-compass in a north and south direction, see if you obtain a deflection of the needle. If, moreover, you labor under the delusion that a surface-sprinkling of the earth near the rods will give an electrical connection, it is best to perform the experiment. It is probable that several acres of lawn would have to be thoroughly sprinkled before a suitable earth-connection could be obtained. A few experiments with a modern electrical machine—a Toepler-Holtz machine, for instance—will readily convince one of the effect of points in dissipating an electrical charge, and of the fact that an electrical discharge always takes the path of least electrical resistance between two points. Having ascertained these facts, one has acquired all the intellectual capital that is possessed by most lightning-rod men. If one apparently discovers that gilded lightning-conductors, or twisted ones, have peculiar attractions for the electrical discharges, one leaves the sure ground of fact for the region of the unproven. The difficulty in our study of thunder-storms is, that we cannot experiment on a sufficiently large scale, and our means are too tardy to allow us to follow the exceedingly rapid changes of electrified bodies. What we call freaks of lightning are merely the expressions of electrical laws, combined with the laws of elasticity of matter. The forked lightning-discharge is an expression of the fact that a positive charge is combining with a negative charge along a path of least resistance; and the air is fractured, so to speak, by the compression, just as a plate of glass yields in zigzag cracks when it is supported on one edge, and a force of compression is applied to the other edge. The influence of the medium through which the electrical discharge takes place can be readily

seen by obtaining the electrical discharge in different gases, such as carbonic-acid gas or nitrogen, and comparing these photographs with those taken in free air. Although we can study certain phenomena of atmospheric electricity successfully in our laboratories, yet we cannot charge a cloud with positive electricity, and fill the sky with different strata of hot and cold air. It is generally believed to-day among scientific men, that the electricity of thunder-storms cannot be attributed to sudden evaporation or condensation of moisture; for direct experiment has failed to reveal any electricity which is due to these causes. Mr. Freeman made many delicate experiments in the physical laboratory of Johns Hopkins university to decide the question whether evaporation produces electricity, and he could find no evidence of any that was due to this cause. Herr Kayser has also lately experimented at the physical laboratory of Berlin upon the electrical effects of condensation, with negative results. Personally I feel that all the experiments hitherto conducted on the electricity due to evaporation and to condensation have been conducted on too small a scale to test the question; and I do not see how they can be conducted on a larger scale. When we think of the immense plan upon which these operations are conducted in nature, of the evaporation from every square foot of the ocean, and of the rapid condensation through miles of space, we can realize that an infinitesimal amount of electrical charge, too small to be detected in a laboratory, might be integrated into a large amount, and, becoming localized, might produce the tremendous electrical disturbances which we witness in thunder-storms.

How, then, can we conduct future investigations upon thunder-storms? The most promising direction for scientific work seems to be in the establishment of systematic observations on thunder-storms, and on atmospheric electricity in general, over a large tract of country. In certain regions, thunder-storms follow certain definite paths, and other tracts are never visited by them. There is a general impression that electrical storms are, in common language, attracted by rivers, and are more severe about large bodies of water in general. However this may be, nothing but systematic daily simultaneous observation, long continued, can increase our knowledge. If the government, in connection with the signal-service, should establish a number of electrical stations throughout the west and south, where thunder-storms and tornadoes are so frequent, daily thunder-storm maps might be issued,

showing the probable path of the electrical disturbances. Perhaps we should then see, in districts peculiarly infested by thunder-storms, certain 'insurance-against-danger-by-lightning retreats,' in which Benjamin Franklin's lightning-rod should rise from a small hut, completely covered with a network of metallic rods which are connected with running water or a large extent of moist earth. These safe retreats would certainly be a great desideratum for many who now suffer greatly from nervous terrors during thunder-storms.

JOHN TROWBRIDGE.

THE FORMATION OF CAÑONS AND PRECIPICES.

ONE of the most remarkable natural objects in the state of New York is to be seen at the crossing of the Genesee River, at Portage station, on the New-York, Lake Erie, and western railroad, 362 miles from New-York City, and 83 from Buffalo. The railway here spans a deep gulf on an iron bridge 820 feet long and 235 feet high, near the upper end of a wonderful cañon. There are three falls of the river immediately below the bridge, measuring 60, 90, and 110 feet respectively. The gorge runs out in the Genesee shales at Mount Morris, being 20 miles long by the meanderings of the river, which falls 500 feet in that distance. In some places the banks are 350 feet high, nearly perpendicular, and the ravine is wholly impassable. It is a fine example of the work of water; and there are hundreds of others in that state, on a smaller scale, in the upper part of the Portage group. One of these is the celebrated Watkins Glen, a beautiful cañon two miles long, with a succession of cascades. The neighboring glen at Havana is very similar; and there are a number of others farther north, several of which may be seen at Big Stream, Rock Stream, Dresden, and other places. Taghanic and Lodi Falls, and the glens and ravines about Ithaca on Cayuga Lake, and many other similar places, are all on the Portage formation, which forms a narrow east and west band across western New York. It might be added, that both Seneca and Cayuga Lakes are, in part at least, simply old Portage glens, now filled with water. To many reflecting persons who, as summer tourists, visit these very curious and beautiful resorts, the thought occurs, why these cañons are in these particular places above all others, and how they have been caused, the work of glaciers, or some convulsion of nature, being